THE REGIME OF HATTAH LAKES

By Geoffrey Robinson
Department of Geography, University of Melbourne

Introduction

On the margins of the Mallee, about 40 miles S. of Mildura, lie the Hattah Lakes, a series of connected depressions which fill by flooding from the R. Murray, and sometimes spill over to adjacent areas. Most of the flood system is shown in Fig. 1. The southern chain of lakes lies within Hattah Lakes National Park but the remainder of the system is in the Kulkyne State Forest, now of little use for timber, some parts being grazed and small areas of sand dunes having completely lost their vegetation cover. Of an area about 14 miles square encompassing the whole flood system, approximately half is occupied by mallee associations and most of the remainder by floodplain associations of black box. The vegetation has been described by Patton (1930) and Zimmer (1937), and other characteristics of the floodplain have been presented by Tate (1885) and in a report by Rowan & Downes (1963, p. 103-105). The network of lakes may represent a former channel of the River Murray, and Hills has remarked upon the recent changes to the Murray's course which seem to have occurred in this area (Hills 1939, p. 317). Whatever the origin of the lakes, however, it is clear that the pattern of stable dunes, together with recently, and even currently, drifting sand, have exerted considerable influence on the present drainage pattern and the conformation of the lake basins.

In all, there are about 17 lakes which are connected with the R. Murray by Chalka Ck, an anabranch flowing about 11 miles from its inlet on the river to the lake system and a further 17 miles to its outlet. To reach the lakes, floodwater enters Chalka Ck at a rock bar across a bend in the river, about 100 miles upstream from Mildura. The bar (Pl. 57, fig. A), in low and moderate flows, confines the river to the inside of the bend but at high flows the body of water impinges on the outside of the bend and, if of sufficient depth, feeds a network of narrow, deep channels (Pl. 57, fig. B), uniting to form Chalka Ck. This effluent water, provided that the flow is high enough and lasts a sufficient time, fills the lakes in sequence and returns to the Murray by the northern channel of the creek, where it is ponded back by the flood peak on the river, after which the return flow is accelerated.

This flood system, until recently, constituted the only one in Victoria remaining completely unaltered and in its natural relationship with the river. During the 1964 flood an earth bank was completed between Lakes Hattah and Little Hattah, in order to retain more water in Hattah after the recession of the flood. This is only a minor modification to a part of the system but, before others are made which may destroy its uniqueness, it is important that as full a knowledge of the system as possible be obtained, in order to both manage the conservation of the area in its own right and to establish a basis for comparison with other flood areas so as to permit assessment of the effects of major artificial modifications. As Jennings

FIG. 1—Hattah Lakes. The map is drawn from aerial photographs to show the approximate maximum confined areas of each lake. Numbered arrows refer to the timing of the flow of water past various points, in days after water entered Chalka Ck in 1964. This information was supplied by E. McDonald.

(1965, p. 155) has pointed out, 'if all the land is modified, it will be impossible or at the least very much more difficult to discern any such effects'.

As a foundation for further studies the pattern of flooding and its frequency over the years were examined in order to establish the regime of the Hattah Lakes.

The Recorded Pattern and Sequence of Events

Since 1908, the Victorian Railways Department has kept monthly records of the depth of water in L. Hattah, the deepest of the lakes, from which water is pumped to the railway halt at Hattah, 2 miles away. These observations were supplemented, during the 1964 flood, by Mr Eric McDonald, the warden of the National Park, who made daily readings of the L. Hattah gauge and observed the wider extent of water in the flood system. Some of this information is shown in Fig. 1 as the progress of floodwater in the 1964 flood. In addition, lines of Red Gums and stranded debris mark the extent of some of the earlier major floods.

The recorded levels from previous floods are summarized in Fig. 2. This shows that in the 56 years of observations at L. Hattah, there have been 35 years when some inflow has occurred, a slightly better average than once every two years, and hence 21 years when there has been no replenishment of the lake. It is normally during the third dry season that the lake completely dries out, the surrounding country being already dry by that time. Two consecutive years of no inflow were recorded four times, in 1913-14, 1929-30, 1937-38, and 1940-41, and three consecutive years of no inflow were recorded twice, in 1943-45 and 1961-63. Over the same 56 years L. Hattah has been completely dry on seven occasions, the longest period being 21 months following the drought years 1943-45. The maximum depth of water observed in the lake was during the 1956 flood, when, following a particularly high flow on the Murray in 1955 a substantial body of water was already in the flood system. The gauge at that time could be read only to 18′ but levelling to well defined strand lines indicated that the water level rose to about 20′. Only 8′ were retained, however, by the closed basin, as in the case with all floods most of the remainder draining back to the Murray after the passage of the flood peak.

The observations made during the 1964 flood were compared with the earlier records, but lack of instrumentation, and the necessarily haphazard observation of some of the lakes lying well outside the park, limit the value of one season's detailed records. Nevertheless, some indicators of past flooding have been tentatively derived. For the southern chain of lakes, from L. Hattah to L. Nip Nip, to be filled by the water penetrating the system, the depth in L. Hattah must reach about 12′. This depth has been observed in 23 of the 35 years of inflow and, in most of the remaining floods, the maximum depth reached would ensure some water in perhaps all the southern lakes except Nip Nip. In 1964 this depth in L. Hattah was reached 26 days after the time water entered Chalka Ck, but the timing will clearly be affected by the amount of water already in the flood system. The lakes to the north fill later and when water entered L. Bittrang, the last of the major network to fill, L. Hattah had 13′ of water, this after 55 days in 1964. Fig. 2 shows that, in addition to the 12 years when the water level in L. Hattah did not even reach 12′, it is unlikely that L. Bitterang received water from 1931 to 1939.

When all the lakes are full, water gradually overflows to surrounding areas, including an intricate complex of sand dunes and box flats to the south-west of L. Lockie. When water overflowed into this area in 1964, L. Hattah had a depth of 13½′, 76 days after the inflow of water to the system. In the past, few floods have put this depth of water into L. Hattah and, from the available evidence, it

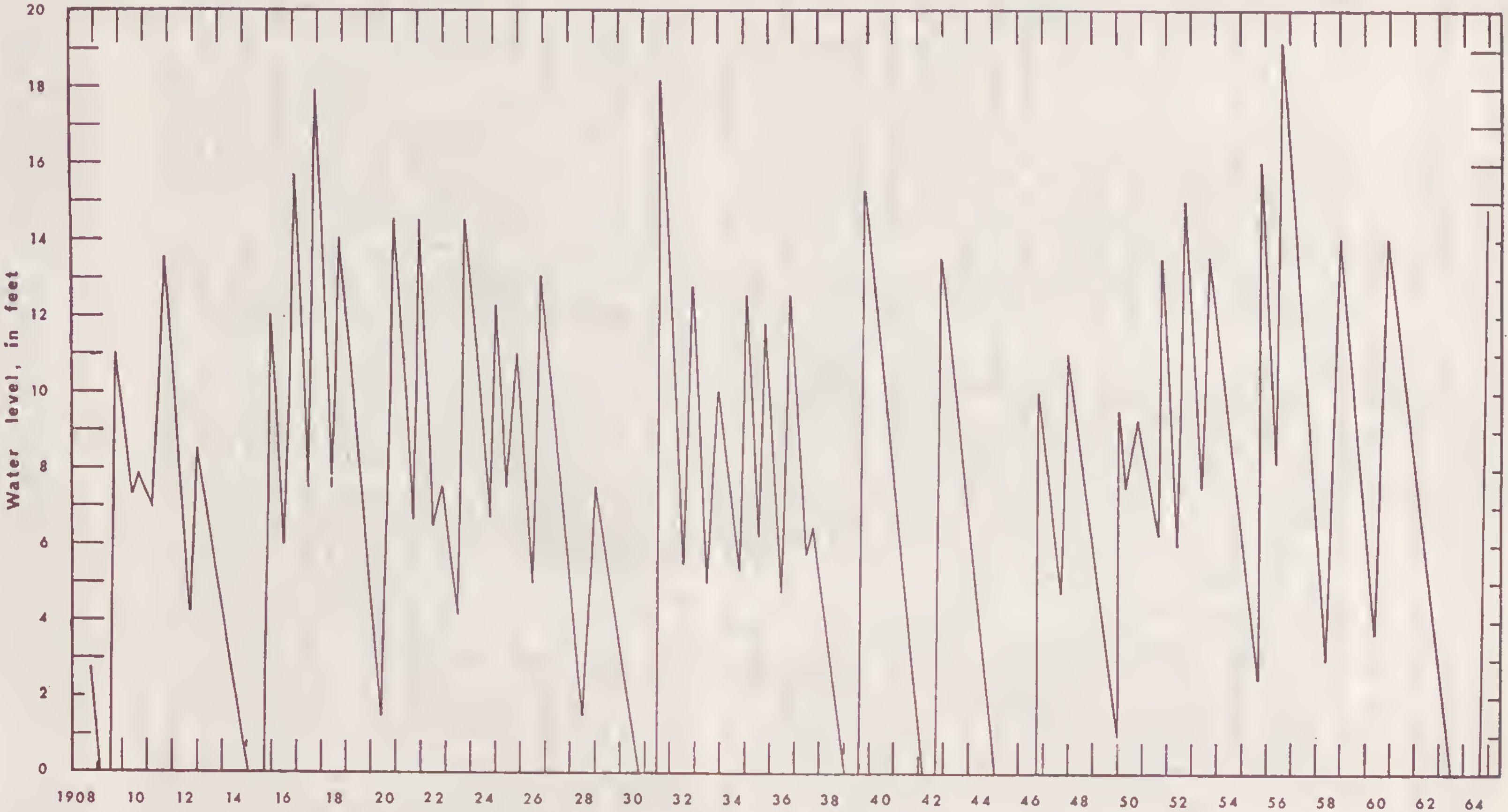

FIG. 2—L. Hattah Water Levels, 1908-1964. Only the highest and lowest levels reached during and after each flood have been plotted, the rises and falls being generalized by straight lines.

is probable that during the three decades after 1920 the sand dune area was flooded only 5 times. The situation is similar where the lakes overflow towards the east. In 1964, after about 83 days of rising water, the eastern lakes overflowed when Hattah reached a depth of 14′. Between 1923 and a series of high floods in the mid- and later-fifties, this depth was reached only in 1931, 1939, and 1952.

This admittedly is an inadequate picture of the sequence and frequency of flooding but it may be a useful basis for observations of future floods which, if there is already water in L. Hattah, may have different depths on the Hattah gauge associated with the various stages of the sequence of flooding.

As the penetration of the lake system by floodwater depends on the occurrence of high flows on the R. Murray, the records for the gauging station nearest upstream from the Chalka Ck inlet were examined in order to establish the relationships between the river flow and the regime of the lakes. From past observations (State Rivers and Water Supply Commission 1946) it has generally been accepted that for water to enter the flood system a corresponding flow of more than 16,000 cusecs must occur at Euston, and for 'flushing' of L. Hattah, so that water extends over a wider area than the confines of the lake depression and therefore joins the return flow to the R. Murray which follows the passage of the flood peak, a flow of more than 20,000 cusecs is required. When maximum flows at Euston, during floods which filled L. Hattah to more than its 8′ basin depth, are compared with the maximum depth of water recorded for each flood (Fig. 3), the high coefficient of 0·97 for linear correlation is obtained and, from regression analysis of the data, 19·7′ on the gauge at Euston, or a flow of more than 19,000 cusecs, will produce a level at the L. Hattah gauge of just over 8′. During the 1964 flood, water overflowed along Chalka Ck during September when the Euston gauge showed levels indicating flows of 18,000 to 20,000 cusecs. All available evidence then supports the use of 20,000 cusecs as the critical flow for flushing of the Hattah Lakes, a flow somewhat higher than a statistically determined 'bankfull discharge' (Robinson 1965). A multiple regression analysis between a number of variables was undertaken (Appendix A) to determine if other factors might have important effects on the depth of water recorded at L. Hattah as the result of a flood. The results of this analysis are expressed in the form:

$$Y = 0{\cdot}65X_1 - 0{\cdot}98X_2 - 4{\cdot}43$$

where Y is the rise of water level in L. Hattah, in feet,
X_1 is the maximum stage of flow at Euston, in feet,
X_2 is the level to which the lake had fallen prior to the flood, in feet.

Table 1 shows the predicted values of Y compared with the actual ones observed. The standard error of Y is 0·74, the greatest deviation of actual from predicted value is 1·5 in 1934 and 1942, the remainder have deviations of less than 1, and most are less than 0·5.

Conclusion

The establishment of the sequence and a comprehensive picture of the pattern of flooding of the Hattah Lakes flood system needs further careful observation during future floods. What have been tentatively derived are some depths of water in L. Hattah to be used as indicators of past flooding. More firmly established by regression analysis is that to predict the rise of L. Hattah to a high order of accuracy we need know only the peak flow of the flood at Euston and the level of water already in the lake. A further question to be asked is to what extent regulation of the R. Murray above Euston has changed the magnitude and frequency of peak

TABLE 1

Predicted compared with observed rises of Lake Hattah

Year	Observed	Predicted	Deviation
1934	7·17	8·70	— 1·53
1935	5·50	5·03	0·47
1936	7·75	8·59	— 0·84
1939	15·25	15·75	— 0·50
1942	13·50	12·01	1·49
1946	10·00	10·57	— 0·57
1947	6·25	5·98	0·27
1949-50	8·50	8·51	— 0·01
1950	1·00	0·99	0·01
1950	1·50	1·85	— 0·35
1951	7·25	7·74	— 0·49
1952	9·00	9·30	— 0·30
1953	5·50	4·62	0·88
1955	13·50	13·43	0·07
1956	11·00	10·18	0·82
1958	10·50	10·30	0·20
1960	10·33	10·07	0·26
1964	14·83	14·71	0·12

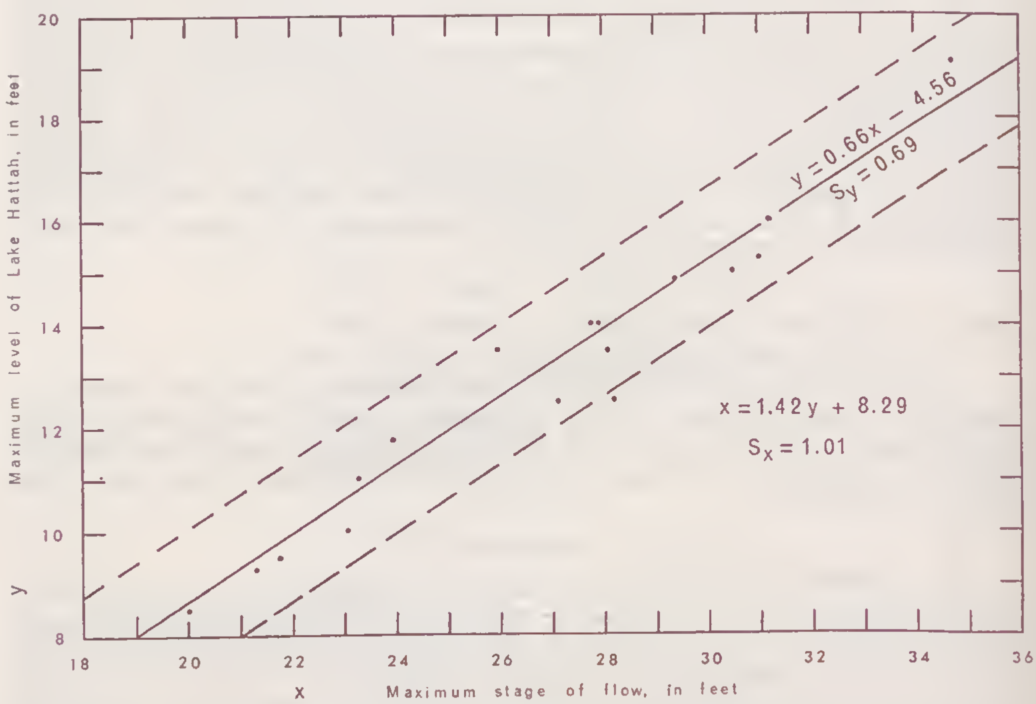

FIG. 3—Relationship of the maximum stage in a flood recorded at Euston and the highest water level reached in L. Hattah. The pecked lines are drawn at a distance of 2 standard erors of *Y* from the regression line.

flows at Euston, and hence altered the scale and frequency of flooding of the Hattah Lakes? This will be dealt with elsewhere.

Acknowledgements

Assistanee from the University of Melbourne Researeh Fund is gratefully aeknowledged, as is the help given by a number of individuals and organizations. Mr E. M. Bibra of the State Rivers and Water Supply Commision supplied hydrographie data, and many other officers of that organization gave freely of their help and advice. The Victorian Railways Department supplied the records for L. Hattah. Mr K. J. Fairbairn eritically read earlier drafts of the manuscript.

Special thanks are given to Mr Eric McDonald, Warden of Hattah Lakes National Park. He made available his observations during the 1964 flood, and on many occasions gave freely of his local knowledge and hospitality. He is a never failing and enthusiastic source of encouragement for workers in the area.

References

EFROYMSON, M. A., 1960. Multiple regression analysis. p. 191-203 in *Mathematical Methods for Digital Computers*, ed. A. Ralston & H. S. Wilf; John Wiley & Sons, New York-London, 293 p.

HILLS, E. S., 1939. The physiography of North-Western Victoria. *Proc. Roy. Soc. Vict.* 51: 297-323.

JENNINGS, J. N., 1965. Man as a geological agent. *Aust. J. Sci.* 28: 150-156.

PATTON, R. T. The factors controlling the distribution of trees in Victoria. *Proc. Roy. Soc. Vict.* 42: 154-210.

ROBINSON, G., 1965. Notes on the bankfull discharge of a regulated river. *Aust. J. Sci.* 28: 23-4.

ROWAN, J. N., and DOWNES, R. G., 1963. A study of the land in North-Western Victoria. *Soil Conservation Authority Victoria* 116 p.

STATE RIVERS AND WATER SUPPLY COMMISSION, 1946. Unpublished report. Correspondence number 46/17381.

TATE, R., 1885. Notes on the physical and geological features of the basin of the lower Murray River. *Trans. Roy. Soc. Sth Aust.* 7: 24-28.

ZIMMER, W. J., 1937. The flora of the far North-West of Victoria. *Forests Commission of Victoria Publication*

Explanation of Plate

PLATE 57

Fig. A—Rock bar across R. Murray at Chalka Ck Inlet.
Fig. B—Main inlet channel of Chalka Ck. This is immediately upstream of the bar in Fig. A.

Appendix A

MULTIPLE REGRESSION TO PREDICT THE RISE OF WATER IN LAKE HATTAH

Data considered relevant to determining a given rise in the water level of L. Hattah were punched on IBM cards for each flood occurring since gaugings began at Euston in 1930. The method of analysis of the data, using an IBM 7044 eomputer, was that deseribed by Efroymson (1960). The programme used to obtain the best fit of the set of observations of the independent and dependent variables is G2-001 in the University of Melbourne Computation Department Programme Library. With this programme, a stepwise multiple regression was earried out on 18 sets of data, each set containing values of 4 independent variables and one dependent variable, the rise of water level. In this method, one independent variable is added at a time, each addition being the one making the greatest improvement in goodness of fit, and a number of intermediate regression equations derived. A variable whieh is approximately a linear combination of other independent variables is not entered into the regression, and only statistieally signifieant variables are retained in the final regression.

The independent variables used in the regression were:

X_1. The maximum stage of flow at Euston in the flood. This is an indicator of the flood's ability to penetrate the anabranch system. From the nature of the build-up of flow and volume of water at a station well downstream in a large catchment area, it is expected that a flood with a given peak will be associated with the discharge of a predictable volume of water. A linear relationship exists between the peak flow and log-discharge of recorded floods at Euston, the Pearson product-moment correlation coefficient being 0·95. If both values were included in the data one would be rejected during regression analysis and the values that were actually observed, the maximum readings on the gauge at Euston, were the ones selected for inclusion.

X_2. The mimium level of the lake before the increment brought by the flood. Clearly, two similar floods may produce rises of different amounts because of differences in the size and shape of the basin which they are filling; the higher the initial water level, the wider the area over which a given volume of floodwater must spread and the smaller the rise in water level.

X_3. Time elapsed since the last inflow of water. Although it was thought that X_2 also represented this, and therefore the drought condition of the territory through which the floodwaters have to flow, there might be some extra weight given to a long drought when the lake level was at zero for several months.

X_4. Precipitation at Hattah over the rising water period. Some storms can produce more than a ½" of rain in a few hours and several inches of rain can fall while the water level of the lake is rising, the maximum being 927 points in 1956. Rain gaugings at Hattah are not complete for the whole period since 1930 and the figures included in the sets of data were derived from the gaugings at Ouyen, using a relationship obtained from the period of record when Ouyen and Hattah were both operational rain gauging stations.

TABLE 2

Correlation coefficients between pairs of variables in multiple regression

	X_1	X_2	X_3	X_4	Y
X_1	1	−0·06	0·10	0·59	0·67
X_2		1	−0·90	−0·08	−0·76
X_3			1	0·15	0·74
X_4				1	0·47
Y					1

Table 2 shows the linear correlation coefficients between the pairs of variables. X_3 was rejected from the analysis as it is inversely related linearly to X_2. X_4 was rejected as being not significant at the 5% level of F. X_1 and X_2 were highly significant at even the 0·1% level of F and were retained in the regression.